An Ontology for State Analysis: Formalizing the Mapping to SysML

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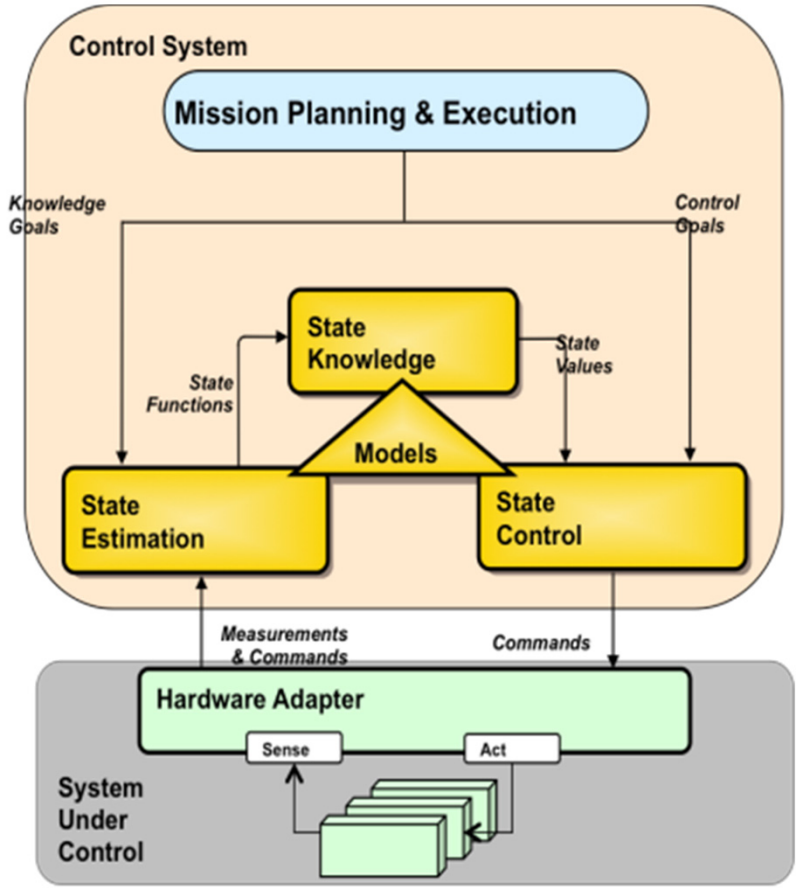
State Analysis

- **A principled methodology for designing complex control systems**
- **Principles from basic control theory and system engineering**
  - Separation between control system and plant
  - Modeling effects between system state variables as a precursor to control system design
  - Making intent explicit in the design and implementation
  - Single controller per state variable
  - Single estimator per state variable
  - Controllers use state estimates as inputs—not measurements

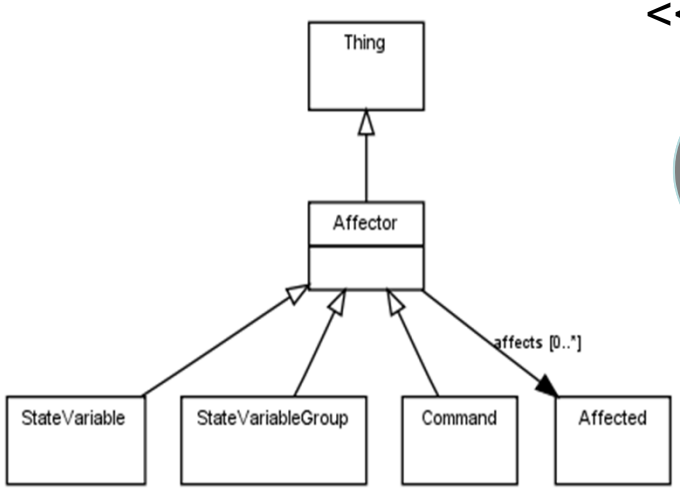


Details: http://mds.jpl.nasa.gov

State Analysis in SysML

- **Modeling is about more than boxes and lines**
- **How do we verify/enforce domain-specific semantic rules?**
  - E.g., only one estimator allowed for any state variable
- **Can we make it easy enough for system engineers to use effectively?**
  - Reduce clutter and clicks
- **Based on SysML**
  - Becoming widely used in industry
  - Supported by multiple COTS tools
- **Add semantic rigor by defining discipline ontologies (in OWL2) and transforming them automatically to stereotype profiles (in SysML)**
- **JPL Integrated Model-Centric Engineering initiative**
  - Provides model transformation between OWL2 and SysML
  - Provides coordination and tooling support

State Effects



<<State Variable>>

Valve position

Describes a property of the plant

<<State Variable>>

<<affects>>

Downstream flow

<<affected>>

<<State Variable>>

<<affects>>

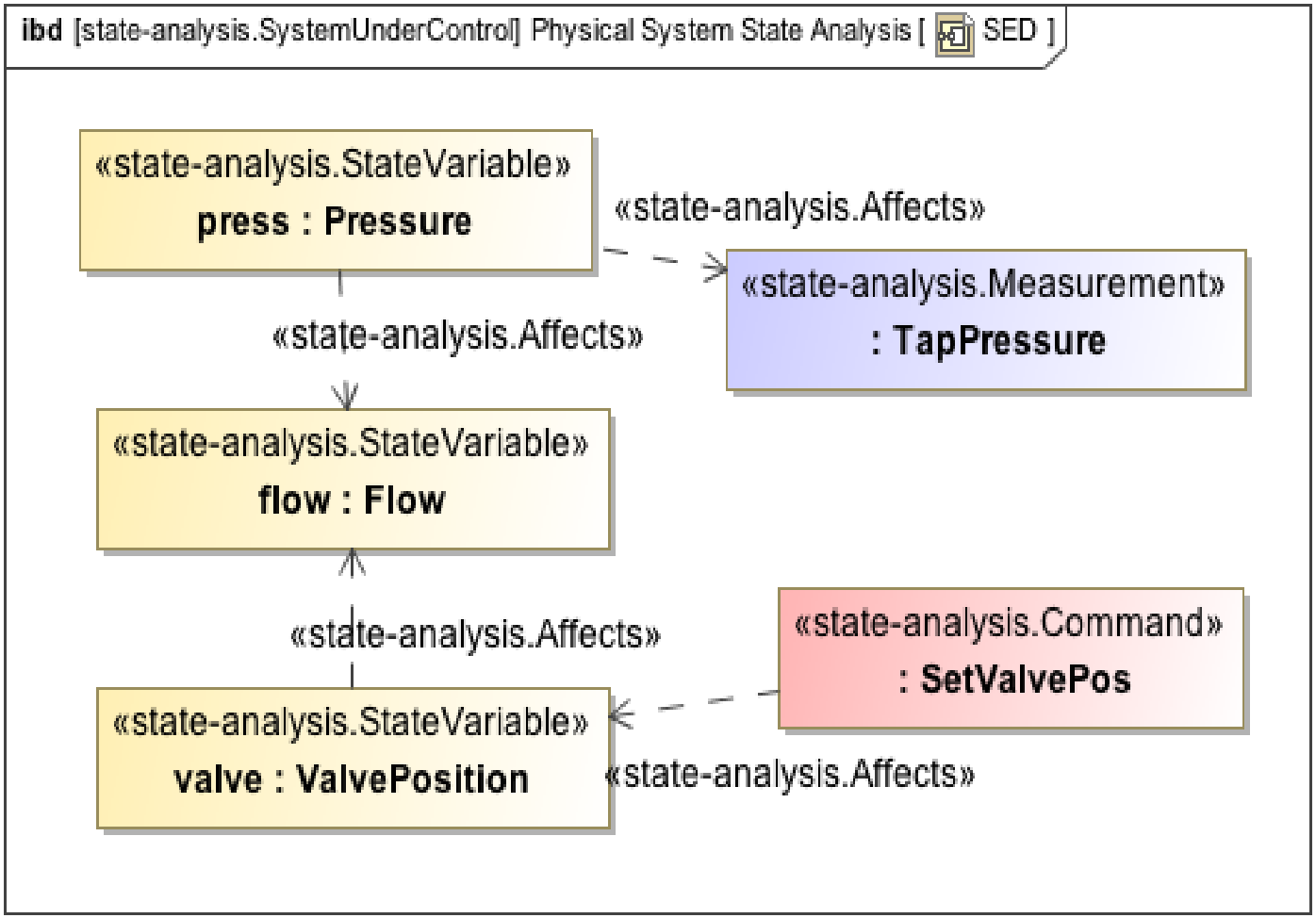
Upstream Pressure

<<affector>>

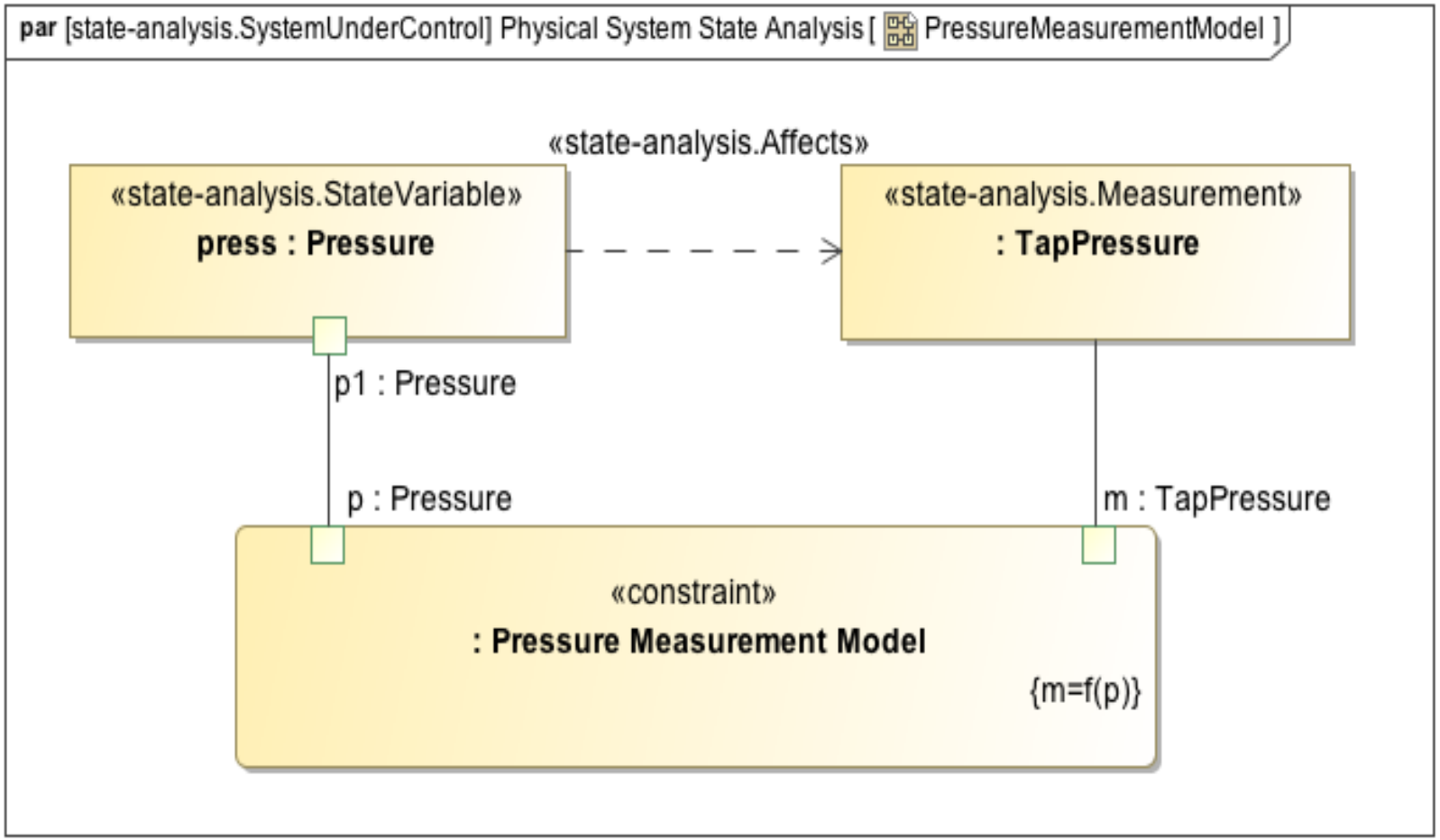
Represents a physical relationship and a choice of directionality in which it will be modeled

Grammar: Subject -- Predicate -- Object

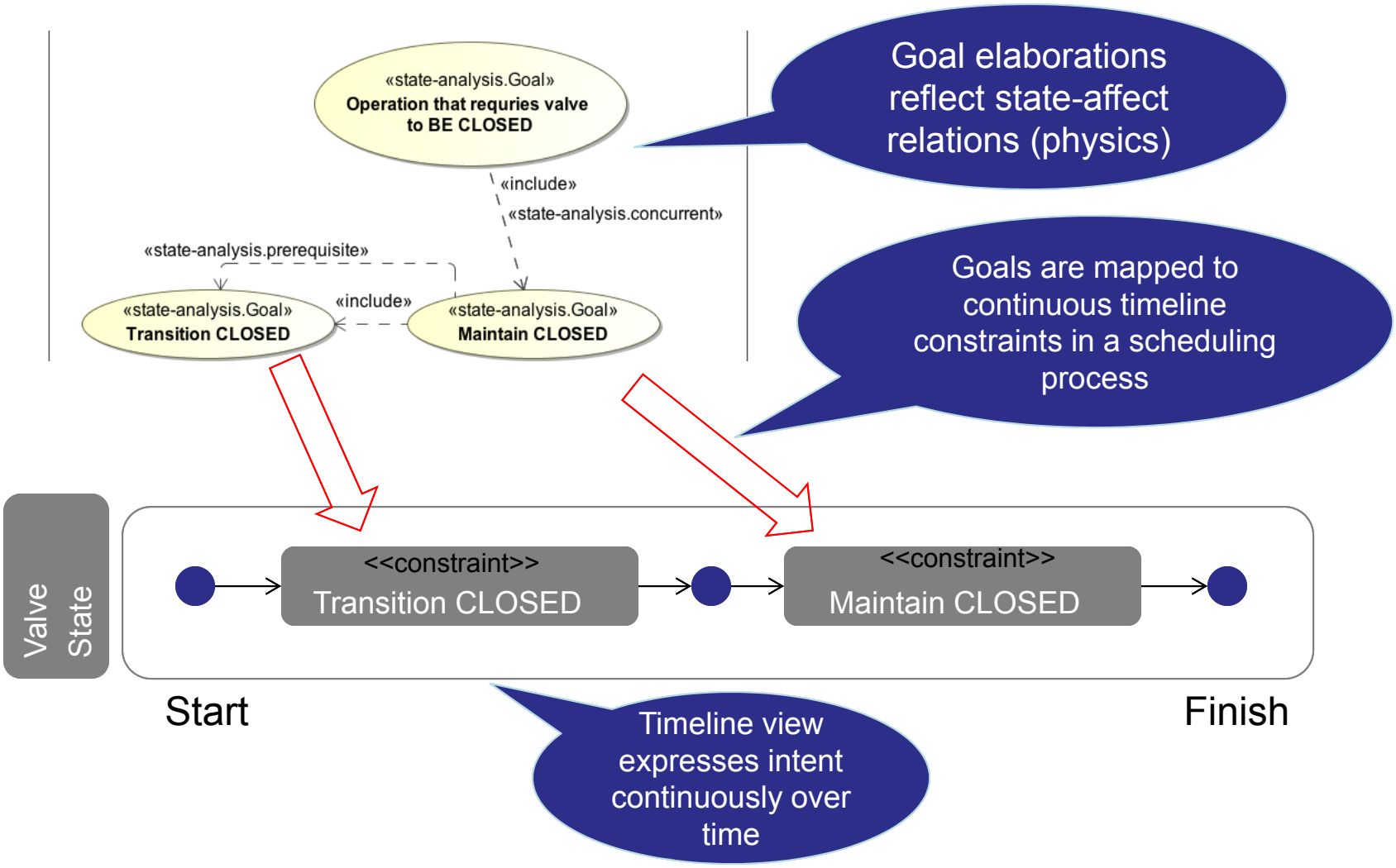
Example in SysML



Model Refinement



Behavior Specification through Goal Networks



What this Enables

- **Domain-specific grammar-aware tooling**
  - Old way: create a block, add stereotype to make it a state variable, create a dependency association to another state variable, add stereotype…
  - New way: create state variable object from menu, tooling automatically knows the only viable relation to another state variable is an <<affects>> relation…
    - Easier, and prevents mistakes
- **Validation of relations not shown in diagrams**
- **Applying stereotyped relations in models allows the model to be analyzed using domain-specific semantics**
- **This work has demonstrated that it is possible to:**
  - define meaningful domain-specific SysML stereotypes using a model transformation from OWL2,
  - apply these stereotypes in a modeling tool, and
  - use them to verify consistency.
- **When complete, the State Analysis ontology and associated SysML profile will enable control system engineers to:**
  - model system behaviors,
  - specify operational intent (plans and sequences), and
  - verify consistency with architectural principles of State Analysis.

Next Steps

- **Formalize relationships with other key domain ontologies:**
  - Mission (work breakdown, components, requirements)
  - Math/Physics (standard physical quantities, units, particularly spatial types)
- **Improve tooling to make it easier to use**
- **Model detailed control system behaviors (control and estimation algorithms)**
- **Export to executable system models, for validation of system behavior**

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